Economic Load Dispatch Solution Using Teaching Learning Optimization

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Abstract- In present power system the ELD (Economic LoadDispatch) is observed as a non- linear problem. Many standard and modern optimization algorithms like PSO, BCO, ABC etc are come up with a solution for the economic load dispatch problems. Among them, teaching learning Based Optimization technique (TLBO) is consideredas the modern searching algorithm. The main objective of this paper is to solve the non-linear problems that takes place in economic load dispatch using TLBO. In general, the non- linear problems in ELD act with the number of constraints. The constraints like voltages, real power, reactive power, shunt capacitor, transformer tapping etc. TLBO contact an optimal solution to the non-linear problem with a good convergence ratio.

Indexed Terms- Economic Load Dispatch, Teaching-learning based optimization, particle swarm optimization.

I. INTRODUCTION

Generator scheduling is vast problem. Since decades, themain important problem of optimization is power system operationis Economic Load Dispatch [ELD]. The electric power productionand the output planning of the required load demand, with the leastfunctioning cost and with equality and inequality of the system conditions are the main motive of the problem of economic dispatch. A lot of methods are developed by researches for Economic Load Dispatch. For any country development, electrical power plays an important role. For getting proper load demand, we should have the optimal power flow generation to minimize the production cost and this could be achieved by ELD with appropriate integration of sources to the load centers. Building effective load flow path while dealing all constraints like voltage, real and reactive power, shunt capacitor etc is the principle goal of Economic Load Dispatch. The quadratic function can be characterized by the cost function of every alternator. Lambda iteration and gradient based methods in convention ELD problems are used to solve the quadratic functions. Long ago, many methodsdeveloped to solve the ELD problems like mathematical programming methods. For start and occasionally converge to local optimum solution or diverge altogether, mathematical programming methods are more delicate. Approaches are quick and effective in linear programming but correlated with piecewiselinear cost is the main poor thing. Approaches in non-linear programming have a convergence struggle and a trouble in algorithm. Many number of equality constraints cannot handle by Newton based approaches. At the present time, the techniques for benchmark functions testing and found better results with good convergence ratio. In recent times, TLBO is considered as one of the finest popular searching algorithms. In this paper, standard ELD functions are applied by the TLBO and TLBO is check out with other searching algorithms. This paper is organized in the order. The second part explains Economic Load Dispatch formulation, third part explains Teaching-Learning based algorithm strategies, fourth part explains the implementation of TLBO algorithm on ELD problems, fifth part discuss the comparison of TLBO algorithm, section six describes the simulation result and analysis and finally section seven, the conclusion that shows the result.

II. ECONOMIC LOAD DISPATCH PROBLEM FORMULATION

Here the non-linear problem with inequality is shown below with two variables x, u and the main aim to obtain the minimum value and it is expressed as

Mini $j\ (x, u)$ (1)

Subject to

$k_n\ (x, u) = 0$ (2)

$j_{min} \leq j\ (x, u) \leq j_{max}$ (3)

The equation (1) shows the primary objective i.e., minimization of cost, the equation (2) shows how to minimizethe considered function and the equation (3) shows the non- linearity by considering the inequality constraints.

Variable x is the representation of state factor. The vector contains the data of power system network real, reactive power, node voltages, and phase angle and represented as follows:

$u = \{P_{G1}. . P_{Gn}, Q_{G1}. . Q_{Gn}, V_{i1}. . V_{in}, \delta_{i1}. . \delta_{in}\}$ (4)

Optimal flow or economic load dispatch having two types ofconstraints:

i) Equality Constraints,

ii) Inequality Constraints.

Equality constraint:

In this constraint, the total power generation is always equal to total load demand (P_D) and losses in the system (P_L) and it willbe represented as

$\Sigma^n_{l=1} P_g = P_D + P_L$ (5)

The above equations exhibit the property of linearity and veryeasy find optimal power generation cost.

Inequality constraints:

Real power generation & reactive power limits of the generator, node voltage limits, and load angle swing limits, transformer tapings, and reactive power support from the capacitor banks are considered.

$P^{min} \leq P_{gi} \leq P^{max}, i = 1,2,3, \dots . n$ (6)

$Q^{min}_{gi} \leq Q_{gi} \leq Q^{max}_{gi}, i = 1,2,3, \dots . n$ (7)

The equation (6), (7) shows the real and reactive power limitations of various generators considered in the proposed system or in a plant is expressed inequality constraints. These two parameters are also helpful to load flow analysis in load bus.

$V^{min} \leq_i V_i \leq V^{max}, i_i = 1,2,3, \dots . n$ (8)

$\delta^{min} \leq_i \delta_i \leq \delta^{max}, i_i = 1,2,3, \dots . n$ (9)

Equations (8), (9) show the node point voltage and load anglewith inequality constraints in the considered testing system.

$T^{min}_n \leq T_n \leq T^{max}_n, n = 1,2,3, \dots . k$ (10)

The equation (10) shows the transformer tap settings considered to adjust proper voltage levels maintenance according to load demand with inequality constraints.

$Q^{min}_{si} \leq Q_{si} \leq Q^{max}_{si}, i = 1,2,3, \dots . n$ (11)

The above equation shows the capacitor banksupport according to reactive power requirement as well as load demand with inequality constraints.

Fuel cost minimization is the primary objective functionand is represented as follows and the function is the costcoefficient equation of each generator [3], [14]. All the equations from (6) – (11), are the non-linear equations and by satisfying the all these constraints to get theoptimal power generation cost. While the traditionaliteration methods sometimes fail to reach the best powergeneration cost.

Considered problem statement and its minimum functionis expressed as

$\min(f) = \Sigma\ f_n (P_{gi})$ (12)

The quadratic nature of the generators used in the powergeneration in thermal power plants.

Where $f_n P_{gi} = a_i + b_i P_{gi} + c_i P^2_{g1}$ (13)

III. TEACHING LEARNING BASED ALGORITHMSTRATEGIES

Teaching Learning Base Optimization is recommended byRao and other colleagues based on Teacher and Learner Mechanism. TLBO is a meta heuristic population-based searchalgorithm like HSA, ANT Colony Optimization (ACO), Particle-swarm Optimization (PSO) and Artificial jBee colony(ABC). To resolve different optimization difficulties TLBO method is a simple mathematical model.

This paper talks about a new optimization algorithm called Teaching Learning Based Optimization (TLBO). According to TLBO algorithm, there are two ways for a leaning in gaining knowledge i.e., is

i. Due to teacher
ii. By interacting with the neighbor learners

In this TLBO algorithm, the beginners called as population.
In TLBO, the deciding phase is the teacher phase and the solution is generated by it that is used for the learner's phase asinputs.

- TEACHING PHASE

Follower gains information from the guide and the mean outcome of class is expanded by guide by his skills. The main aim of the teacher is to increase the learner's knowledge and boost the percentage of exam clearing learners. All learners are not cleverness so, practically it is not possible. Consider,

T_i = Teacher at any iteration iM_i = Mean value

To more towards its own knowledge level, T_i makes the meanvalue M_i i.e., T_i chosen as M_{new}.

Therefore, the best learner treated as teacher. The difference of current mean result of every subject and the equal result of the teacher for every subject is specified as,Difference = r*(M_{new}-$T_F M_i$)

Here, T_F=Teaching factor and it is specified as follows:TF=round*[1+round*(0.1) *{2-1}]

The existing solution is modified by this difference accordingto the following expression,

$X_{sol\ new}$=$X_{sol\ old}$ +difference

- LEARNER PHASE

In learner phase, the teacher identified one intelligent and the knowledge of the learner is improved bysharing the knowledge with other learners. So, in this wayboth the learners are improving their knowledge. Then, compare the difference of mean value of two learners, at this stage better learner act as the teacher. The learner phase is as follows,

Select two learners $i \neq j$

$X_{sol\ new} = X_{sol\ old}+r*(x_i-x_j)$ if $f(x_i)<f(x_j)$
$X_{sol\ new} =X_{sol\ old}+r*(x_j-x_i)$ if $f(x_i)<f(x_j)$

IV. IMPLEMENTATION OF TLBO ALGORITHMON ELD PROBLEMS

STEP 1: Initialization of population.

STEP 2: Generating criterion of termination.

STEP 3: Govern the design variables mean value of each one.

STEP 4: Best solution is recognized and the variables areestimated.

STEP 5: Estimated variable values ae updated based on theavailable best solution using

$X_{sol\ new} = X_{sol\ old}+ r*(M_{new} - T_F M_i)$

STEP 6: Check whether updated solution is better than currentsolution or not. If it is no rejects the updated solution. Continuewith old solution.

STEP 7: If the updated solution beyond existing solution then we randomly select two set of solutions as X_i and X_j.

STEP 8: Two solutions are updated by considering $X_i>X_j$ and$X_j>X_i$ in two different ways.

STEP 9: Now compare the two different cases. If any case interrupts the limits rejected the solution whether the both solutions satisfy all the limits then consider the best solution among them.

STEP 10: Check whether the solution satisfies all theconstraints or not.

STEP 11: If the solution does not satisfies then move to meandifference of design variables STEP 3.

STEP 12: Otherwise consider it as the global best solution.

In this application of Teaching Learning Based Optimization based ELD solution, all the cost curve function data is read, calculated the mean value of all generators based on the population used in this algorithm.

In this application of TLBO, the students are considered as economic load dispatch problem solutions. Here subject is considered as different constraints. The student able to satisfy minimum levels, which get the finest among the remaining students, then that student is treated as best and in this algorithm application the student is considered as the best solutions of ELD. The important aim of ELD is to minimize the cost function. So, from the obtainable values, the local minimum value is considered as started from this point. Once the teacher phase started, the knowledge levels of the learners are improved by the teacher (whether the available solution issatisfied or not when it is tested with all the constraints) and the new knowledge level (new solution) is applied by equation

$$X_{sol\ new} = X_{sol\ old} + r*(M_{new} - T_F M_i)$$

The new solution is applied from the teacher phase then all the possible solutions are applied by ending of teacher phase. Then the learners phase begins here,all the learners are interacting with each other (solutions that are available from teacher phase are compared). When the maximum iterations are reached by the algorithm, the best learners become the teacher (among all the available solutions only one solution is treated as the best one like the global best solution by all the constraints satisfaction and minimum cost value comparison).

V. RESULTS & DISCUSSION

The TLBO algorithm is tested on the standard test system IEEE-30 bus system which consists of sixnumber of generators in various locations in the network, each generator has its own cost coefficients and cost curve [9], [10], and [13]. The generator active power limitations are considered here as shown in table 1 along with price coefficients [3], [5]. #indicates the generator is in the working condition; sometimes generators are kept in banking mode and shunt-down when load demand is comparative less with the generated power as per historical data and load predications.

Table 1: Standard Power plant with six generators limitations data "IEEE-30 bus system"

Generator number	Price cost coefficients			Min MW	Max MW
	a	b	C		
#1	0.0	2.00	0.00375	50	200
#2	0.0	1.75	0.01750	20	80
#5	0.0	1.00	0.06250	10	50
#8	0.0	3.25	0.00834	10	35
#11	0.0	3.00	0.02500	10	30
#13	0.0	3.00	0.02500	12	40

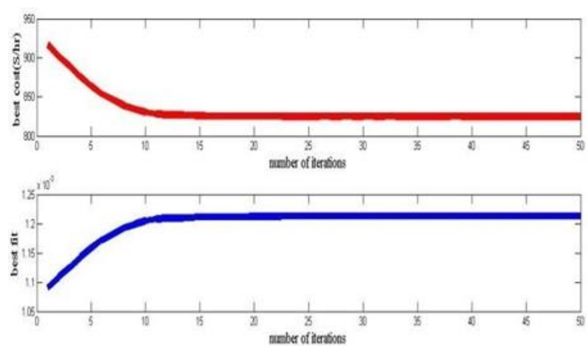

Figure 1: after completion of 50 iteration fuel cost under loaddemand 283.5MW.

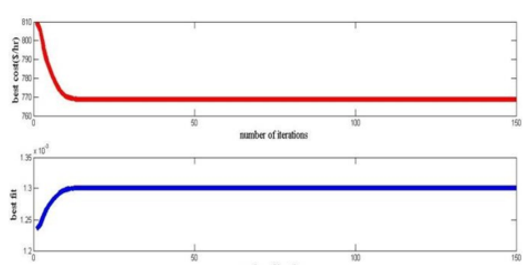

Figure 3: after completion of 150 iteration fuel costunder load demand 283.5MW.

Figure 1, 2, &3 shows the simulation results of IEEE-30 bus system under load demand of 283.5MW with various levels of iterations 50, 100, &150. These iterations show the smooth curves & indicate the fast convergence to obtain the optimal generation cost while satisfying the all constraints considered in equations (6)-(11).

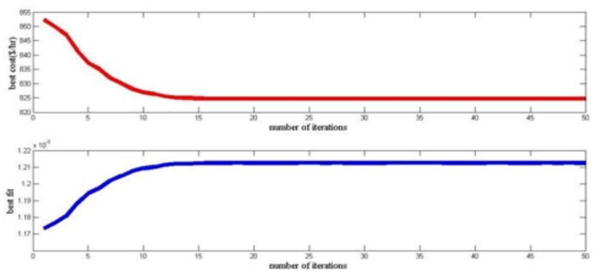

Figure 4: after completion of 50 iteration fuel cost under loaddemand 300MW.

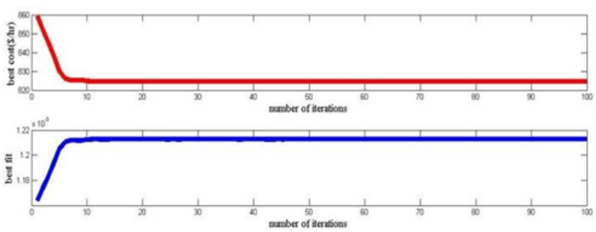

Figure 5: after completion of 100 iteration fuel cost under loaddemand 300MW.

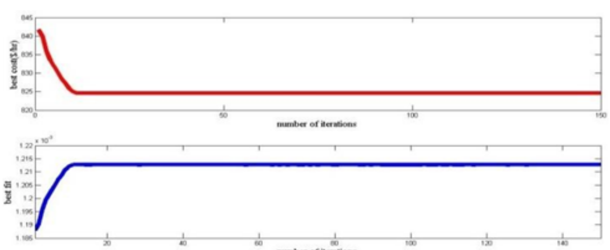

Figure 6: after completion of 150 iteration fuel cost under loaddemand 300MW.

Figure (4)-(6) shows the simulation response of optimal cost under load demand 300MW with various iterations 50, 100, & 150. The cost, fitness curves smooth and indicate the fast convergence at early iterations. To examine the proposed algorithm, high number of iterations are considered even the optimal cost is reached at 50 iterations, by considering the 150 iterations it indicates local minimal trap is avoided by the proposed TLBO algorithm.

Teacher learner-based optimization algorithm is tested on benchmark 30 bus system with two distinct conditions byvarying the load demand. Generally, the 30-bus system load is 283.5MW, using TLBO the generated power sharing between the generators is simulated with different iterations for better evaluation of the algorithm. By changing the load demand to 300MW is also simulatedwith different iterations for evaluation and one change canobserve here the power generation in #5 is not changed in load demand 283.5MW in all iterations due to its price coefficients, but when the load is changed to 300MW thegenerated power value is increased and the total cost value reduction is observed in last two iteration columns. Generator #13 price coefficients are comparatively high and this generator is always operated in minimum power generation condition.

Table 2: Generation cost comparison with TLBO, PSOand conventional Gradient approach.

Units	Min	Max	TLBO	Gradient Based	Power simulator world
1	50	200	185.40	187.219	197.99
2	20	80	46.87	53.781	44.00
5	10	35	10	16.955	22.00
8	10	30	10	11.288	10.00
11	15	50	19.12	11.287	10.00
13	12	40	12	13.353	12.00
Fuel cost($\hr)			767.6021	$804.853	$811.5

Table 2 shows the optimal power generation cost of IEEE 30 bus system under same constraints with three different approaches compared and the proposed algorithm shows the superiority and the optimal cost sounds the algorithm robustness andaccuracy with a smaller number of control variables.

CONCLUSION

Proposed algorithm tested and satisfies the various equality and inequality constraints which are considered in optimal load dispatch. The optimal solution of economic load dispatch gives the best generation cost and load demand is shared according to their generation cost function solutions obtained by TLBO. Here the algorithm is tested with different load demands while is the TLBO is sustained for dynamic changes in the power systems. For better time convergence understanding purposes the different iterations are considered along with load demand conditions which are used in ELD problems. Under all the tested conditions optimal cost isobtained without violating the generator limits in any condition. The optimal solutions is also achieved in less no. of iterations with this algorithm but for any possibility of changes it is tested up to 150 iterations andat each is trial 10 means values are considered.

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